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Workshop on the Establishment of a
Consultative Group on Solar Energy
Research and Applications (COSERA)

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ESTABLISHMENT OF COSERA: ISSUE PAPER*

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by the
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International trends in solar energy research and application

1. In spite of the changing scenarios of prices and availability of alternative fuels, research and development relating to the utilization of solar energy is proceeding and the costs of solar energy components and equipment are declining. Neither of these developments is taking place at a pace which is needed but it is still clear that notwithstanding the present relatively high cost of solar energy, countries have to prepare themselves for large-scale utilization of solar energy though within a somewhat uncertain timeframe. In the meantime solar energy research and application seem to be reaching the cross-roads.

2. In the case of photovoltaics for which more information is available than for other categories of application or research, the actual worldwide shipments, which up to 1984 were increasing, appear now to be stagnant. It has been clear to the industry and to its "watchers" that the earlier projections of the growth of markets for solar photovoltaics have been too optimistic. Long-term forecasts for the year 2000 and beyond, however, continue to be optimistic, particularly because of the rapidly increasing conversion efficiencies (from 1 to 2 per cent in 1976 to 11 to 12 per cent in 1985).^{1/}

3. In regard to solar thermal energy, a 1986 report of the United States Solar Energy Industries Association came to the conclusion that "few in the industry expect the market to develop until energy prices rise or federal subsidies for conventional energy technologies and the major question is whether they will rise soon enough to save the industry from dissolving and the technology base from evaporating".^{2/}

4. The trends at the international level relating to research and expenditure on solar energy are worth noting.^{3/} In the case of the United States where substantial public spending of solar R&D took place there is now a trend of reduction and setbacks in public sector R & D from 561 million in 1980 to 52 million forecast for 1987. The development of solar technology in the major producing countries has

relied heavily on public sector support at three main levels: support for R&D, provision of markets, and raising public awareness of the technology. The support for R&D has been conducted as national programmes and the expansion of the market has involved international agencies and led to the application of photovoltaic technology in the developing countries. While the R&D programmes set price goals in levels of efficiency to be achieved over specific time scales, the expansion of markets provided finances as well as operating experiences that were subsequently used in R&D. Most of the R&D in the United States, Western Europe and Japan has been done through complex government-industry, industry-university and government-university interlinkages. While the quantum of publicly funded R&D in the United States has been declining, different trends are visible in Europe and Japan. West European countries under the auspices of the European Economic Community launched a major programme in the late 1970s involving state agencies, universities, industry and public enterprises. Photovoltaics R&D accounted for US\$15.5 million over the 1975-79 period and was increased by some 190 per cent to reach US\$59 million over the 1979-83 period. The work in Europe was subcontracted to universities, research institutes and industry in the various European countries. Like the US, the EEC programme undertook R&D specifically to reduce selling costs by improved processing and alternative materials. The various European countries also support photovoltaic R&D through national programmes. France, for example, has set aside US\$154 million for photovoltaic development over the 1982-86 period of which the Government's contribution amounts to US\$52 million. The FRG Federal Ministry for Research and Technology spent the following amounts on photovoltaics research: In the years 1972-1977 DM10 million (i.e. 4.5 per cent of total appropriations for research on non-nuclear energy); in the years 1978-1982 this was increased to DM 95 million (9 per cent of total); from 1983-1987 research expenditure on pv reached an all-time high of DM300 million (28 per cent of total); and forecasts for the period 1988-1992 expect a decline in non-nuclear research funding from DM1.1 billion in 1988 to DM810 million in 1992, with a corresponding reduction in pv research from DM270 million in 1988 to DM160 million in 1992 (26 per cent and 20 per cent of total, respectively).

5. Photovoltaic R&D in Japan is conducted under the "sunshine project" launched in 1974. The funding for photovoltaics has been increasing rapidly. For example, the funding was raised over 140 per cent during the 1980-82 period alone, bringing the total allocation to US\$30 million. By 1984 Japan was spending some US\$16 million on photovoltaic R&D, equally shared by industry and the Government.

6. Even with the recent reductions in some national R&D budgets, it has been estimated that some US\$100 million per annum is spent worldwide on pv research.

7. Some amount of information is also available about the trends in developing countries. The photovoltaic applications in developing countries have been made primarily through the efforts of some companies and through international agencies. The United Nations Development Programme, for example, has funded a World Bank-executed project on photovoltaics. The finding of workshops organized by UNDP recently have resulted in the conclusion that after numerous demonstration projects during the period 1975-83 photovoltaics has been proven to operate in remote locations and even under harsh conditions.^{4/} Photovoltaics is an economically competitive source of electric power for many applications and in many locations. Such applications now particularly improved remote power for clinics, schools and other buildings, refrigeration for medicinal vaccines, water pumping for livestock, irrigation, and clean drinking water, and communications. Financing institutions, such as the World Bank, African Development Bank and Asian Development Bank are prepared to finance economically sound uses of photovoltaics as a component of a rural, agricultural energy development programme or a rural health scheme.

8. In regard to production in the developing countries a start has been made, though there has been no significant commercialization of photovoltaic systems from local R&D. So far their output has only changed from a minuscule 0.2 unit mW in 1983 to 0.70 mW in 1984.^{5/} The largest growth rate appears to have been recorded in India while the rest of the developing country shipments is accounted for by Brazil and Singapore which have assembly facilities. Saudi Arabia has set up a

single custom module plant aimed at supplying local and regional markets. At the same time the developing countries have remained targets of photovoltaic commercialization despite the disappointing sales in the last five years. The EEC is a major supplier of modules to these countries as part of their aid programmes. Individual countries, such as Italy and France ship over half of their photovoltaic output to developing countries, mainly to Africa.

Trends in solar research and development in developing countries

9. A review of research institutes in developing countries carried out by UNIDO in 1982 and updated in 1985 and 1986 showed that out of 115 institutes included in the most recent review, 6/ 43 were involved with the research of photovoltaics (solar cell technology and systems) and 25 with solar thermal (flat plate and concentrating) collectors; 15 with solar thermal systems and 6 with selective coatings. Main applications were solar drying (47), water heating (33), cooling and refrigeration (24), solar cooker (16) and water pumping (13); 6 were engaged in research in industrial heat process. The expenditure on research and development does not, however, appear to be considerable. An analysis of the research budgets for 1984-85 of institutes listed in the above review, shows that these budgets range from US\$10,000 to several million dollars. At the low end of the scale are Iran, Trinidad and Tobago and Cameroon while Singapore and the Kingdom of Saudi Arabia are on top of the list with 12 and 8 million, respectively. The great majority, however, have a rather modest budget of 100,000 to 200,000 with an average professional staff of five.

10. Annex I shows a list of research institutes in developing countries and their areas of research and the co-operation they are currently having with institutions in other countries. The table shows clearly that a certain amount of co-operation already exists in solar energy research. Such co-operation has taken different forms, such as co-operation with aid agencies, non-governmental development-oriented organizations, governments and United Nations organizations. It is interesting to note that several cases of co-operation between developing country institutions themselves also exist.

11. At the same time it is clear that constraints are faced by developing countries in regard to research and more particularly in regard to commercialization, which appears to be a weak link. Even with regard to the manufacturing activities undertaken in developing countries, many of the applications would appear to be based on imported technologies. One recent Swedish study noted that "the lack of contact and co-operation between many scientists in the developing world is a major obstacle to a more rapid introduction of solar systems. Countries such as Egypt and Kenya, both have well-reputed research institutes and local manufacturers, but contacts between these parties are few and occasional".^{7/} Nevertheless, it is evident that a great deal of interest in further co-operation exists as is seen from Annex II which presents the information collected by UNIDO on the interest evinced by institutions in various countries in co-operating with institutes outside. Interest in co-operative research has been expressed by 14 countries in photovoltaic systems, 11 in solar drying, 10 in solar cells, 9 in water heating and 5 in solar collectors.

Some existing forms of co-operation

12. In regard to international co-operation in general it is useful to take note of some of the existing attempts at co-operation which are, however, primarily at the regional level.

13. The European Network for Solar Energy Co-operation was formally launched in September 1983 at the initiative of UNESCO. UNIDO is also a member of the network. Bulgaria, USSR, Hungary, Rumania, Poland, Yugoslavia, Israel, FRG and France are reported to be in the Network Committee. Working groups have been set up with focal points in different countries in regard to solar water heating, heat storage, solar drying and another working group on photovoltaics and its applications. The types of activities identified relate to the exchange of personnel, working in participants' laboratories and impartial assessment at the highest intellectual level. It has been agreed that the collective knowledge of the European Network would be available for the encouragement of the developing countries and that a wasteful duplication of individual projects could be eliminated by co-operation.

14. In regard to the ESCAP region projects are reported to be implemented at the regional level in research, development and demonstration on solar photovoltaic systems in co-operation with the Government of Japan.

15. Based on the expertise acquired through national and bilateral projects in Indonesia and Pakistan in photovoltaic power generation, assistance is being provided to developing countries in the region and for sharing experience as well as the training of engineers and technicians in the establishment, operation and evaluation of solar photovoltaic systems. The Indonesia-Japan photovoltaic power generation system project is proposed to be used as a regional research, development and demonstration project.

16. A Silicon Technology Development Institute has been established in Pakistan through a project funded by the Government of Pakistan and UNFSSTD and implemented by UNIDO. It provides an excellent nucleus for training, research and pilot production of complete PV arrays, starting from quartz and can be strengthened for co-operation with other developing countries.

17. In the ESCWA region network on new and renewable sources of energy (mainly solar) is being established. A meeting on solar and wind energy will be held in November 1986 in the ESCWA region.

18. In regard to the African region, the Solar Energy Society of Africa was established in November 1983 and its research priorities include solar crop drying, water supply for irrigation, solar maps and airconditioning including passive heating and cooling. The activities envisaged for this society include organization of seminars, exchange of personnel, material and equipment, establishment of links with other proficient organizations, development of co-operative programmes, preparation of directories etc.

19. The International Solar Energy Society, a worldwide non-profit organization founded in 1957 and with members in more than 90 of the world's countries is widely regarded as the premier body of its type

operating in the solar energy field. It has consultative status with the United Nations as a non-governmental organization. The Society has among its members most of the world's leading figures in solar energy research and development.

20. The Society convenes biannual world congresses as a multidisciplinary forum for experts to review and compare notes on latest developments of solar technology and also organizes an international solar equipment exhibition in conjunction with each congress. After Brighton, UK (1981), Perth, Australia (1983) and Montreal, Canada (1985), Hamburg, FRG has been selected for the 1987 congress.

21. The rather brief and limited review of some of the existing efforts of co-operation would show that useful beginnings have been made. However, it is not at all evident that the resources available for solar energy research and application are significantly increased or are being coordinated in a way which is necessary to impart a decisive thrust to this field, which is of particular importance to developing countries and to global energy issues in general.

22. A number of aid agencies have been meeting informally from time to time to discuss their support for research relating to energy in developing countries.^{8/} The first two of these informal meetings were organized by IDRC in April 1982 and September 1984. A third meeting was held at the GTZ Headquarters in May 1986. It should be noted that these were informal meetings for the energy sector as a whole and no particular focus was put on solar energy. Developing countries do not appear to have been represented at such meetings. It may also be noted that while global networks have been created for biomass (Biomass Users Network) and rural energy (Rural Energy Technology and Innovation Network) no such network exists for solar energy. It is reported that the participants in the informal donors meetings expressed concern that in light of the volatile energy market, developing countries should not be discouraged from taking the necessary energy investment decisions. The participants also decided that donors should increasingly focus their support on research into energy-related development constraints and opportunities. The final results of the IDRC's Energy Research Group were also discussed

and among other things attention was drawn to the following: research must be demand-oriented; user-oriented strategies are needed; energy research priorities must evolve as a result of policy decisions; and research capacities must be built up in developing countries.

Need for a Consultative Group on Solar Energy Research
and Applications (COSERA)

23. The foregoing makes it clear that a stage has been reached where a more decisive thrust towards co-operation is needed. Among the factors contributing to this result are the following: the relatively stagnant trends in solar energy equipment production and shipments; the somewhat conflicting trends in regard to the quantum of research funds being channelled into the field of solar energy; the availability of a certain amount of experience in the utilization of solar energy equipment by the developing countries; the existence of a large number of institutions in developing countries doing research in the field of solar energy; and not least the expressed desire for international co-operation. This together with the ongoing, though limited, co-operation at the regional level provide the scope for the establishment of a Consultative Group on Solar Energy Research and Applications (COSEPA) at the international level with the aim of promoting a critical mass of international effort related to solar energy research and application, in particular for the benefit of the developing countries.

24. The context of UNIDO's involvement in promoting the Group may be set out at this stage. UNIDO has been working in the field of solar energy by way of information collection and dissemination, preparation of studies and directories and specific technical assistance projects (for example in Afghanistan, Comoro Islands, Cuba, Ethiopia, Jordan, Mali, Niger and the Sudan). As part of its programme for strengthening the technological capabilities of developing countries in the fields of new and emerging technologies the UNIDO Secretariat brought up the subject of solar energy at the International Forum on Technological Advances and Development, held in Tbilisi, USSR, in April 1983. The Forum recommended in its report^{9/} the establishment of a Consultative Group on Solar Energy

Research and Applications (COSEPA). The particular interest of UNIDO is that solar energy research must not only be accelerated as a longterm energy imperative but the beginnings of a solar energy industry have to be nurtured in many developing countries watched by the strengthening of the relevant scientific and technological capabilities. The growth of such an industry is likely to be substantially hampered if the developing countries do not have a measure of research and application capacity. The building of systems for local use requires essentially local knowledge and local research capabilities which will then have to be related to the local manufacturing capabilities. This is not to argue that the work in developing countries should be confined to applications or that they should not go into the field of research in fundamental areas. The creation of an international group will actually open up the possibilities of co-operation and avoidance of duplication and of accelerating results where a certain measure of excellence has already been achieved.

25. In the activities of such a group at the international level it should, however, be borne in mind that existing regional networks must be utilized; national capacities should be fostered and activities at the international level should not be at the expense of those at the national level; there should be no attempt to "reinvent the wheel" and on the other hand, stress should be put on avoidance of duplication consistent with the growth of national capacities in the manner desired by individual countries and translating the research into actual application and production. A consultative group, however, can function effectively only if sufficient funds are available and has as its members key actors in this area including donor agencies and several "centres of excellence" or high-level institutions in developing countries. It is in this context that attention has to be given to the experience of the Consultative Group on International Agricultural Research (CGIAR), the set-up of which is explained later in this paper. The UNIDO Secretariat believes that next to agriculture, solar energy is an area deserving attention considering its renewable nature and its importance to all countries and in particular developing countries. Hence a group modelled on the CGIAR but not necessarily to be on all fours with that body would be useful.

26. A Consultative Group on International Solar Energy Research and Applications could take various forms. Typically several activities could be envisaged, such as information exchange, training, joint research and development, periodical review of the state of the art, measures to promote the commercialization of the technologies developed, etc. A consultative group of this type could also promote specialized "centres of excellence" with regional or international scope in specific subject areas. In addition, it could be directly linked with funding for research, following the pattern of the Consultative Group on International Agricultural Research (CGIAR). The last element is critical, if the group is to achieve the desired results.

Experience with the Consultative Group on International Agricultural Research (CGIAR)

27. The CGIAR established in 1971 under the joint sponsorship of the World Bank, UNDP and FAO is an informal association of governments, international and regional organizations and private foundations dedicated to supporting a system of agricultural research centres and programmes around the world. CGIAR operates without any legal charter, written rules, protocols or by-laws, inter-alia, by the common consent, shared interest and good will of its members. Members of the CGIAR meet annually to consider programme and budget proposals, policy issues and other matters from the centres. The initiative was taken on the belief that long-term support for an expanded international agricultural research system should be provided. It is widely recognized that this experiment has been highly successful. Annex III shows, for example, that the contributions to CGIAR for the first ten years of its operation increased more than fivefold from US\$20 million in 1972 to US\$119 million in 1980. Annex IV gives additional information covering the period up to 1985.

Proposal for a Consultative Group on Solar Energy Research and Applications (COSERA)

28. Based on the foregoing it is suggested that careful consideration be given to the establishment of a Consultative Group on Solar Energy Research and Applications composed of R&D institutions, particularly from

developing countries, and donor agencies with the aim of imparting direction and cohesion to and increasing the size and accelerating the speed of international research effort in the field of solar energy, particularly for applications in developing countries. It will draw upon the experience of CGIAR but need not necessarily be identical in organization. The COSERA could also have a certain amount of emphasis on industrial production and application. It should, however, be remembered that such a group need not be an intergovernmental group but could be organized as an informal group of those donors and research institutions willing to participate. The Group will not "dictate" what needs to be done in individual countries but rather try to harmonize to the extent possible individual national efforts with international research concerns and the approach of donor countries. It will have to function with a minimum of legal or bureaucratic constraints. However certain "rules of the game" will have to be observed and there will be a minimum level of obligation on the part of the donors as well as on the part of the participating research institutions, particularly in regard to provision of information and willingness to discuss the results of their various efforts and experience, particularly relating to developing countries. COSERA will not preclude any bilateral co-operation now or in the future, nor will it substitute the individual efforts of countries or hinder or replace existing commercial flows. On the other hand, it is believed, that this group could contribute both to the creation of a solar energy industry in developing countries by promoting more concentrated research and linking it to industrial application and also to the opening up of potential markets for international commerce. The group will also establish links with the efforts of agencies in the United Nations system.

29. It would appear that considering the present stage of solar energy research and application and the need for a more concerted effort as well as for a long-term support of a critical mass, the creation of a Consultative Group on Solar Energy Research and Applications (COSERA) drawing, among others, on the experience of the CGIAR, is both timely and essential. Based on the inputs provided by various participants in the workshop, it should be possible to establish the COSEPA after appropriate consultations with all interested donor agencies and as many developing country institutions as possible and after elaboration of its proposed

institutional framework. The present workshop has necessarily to be limited to a few expert participants and observers, the intention being to concretize the thoughts in this respect a little more before reaching out to a wider level of participation.

30. The workshop may like to discuss the foregoing and arrive at proposals for concrete further action in this matter, and in particular for UNIDO to:

- (a) prepare for and convene a meeting of all interested institutions to establish the COSERA; this would include the surveying and identification of interested R&D institutions, detailed consultation with donor agencies, and elaboration of the framework of the group.
- (b) identify subject areas of research and application where efforts at international co-operation may be primarily directed; and
- (c) concurrently build up a portfolio of R&D projects in developing countries to be promoted and assisted by international co-operation. (It is requested that participants bring for this workshop concrete proposals for co-operation in research and application.)

Footnotes

- 1/ Figures quoted in this paragraph are taken from different issues of Solar Energy Intelligence Report
- 2/ Solar Energy Intelligence Report, 25 February 1986.
- 3/ Figures in the rest of the paragraph are taken from draft report for UNIDO by K. Hoffman "Technological and Commercial Trends in Photovoltaics".
- 4/ See report of UNDP Renewable Energy Information Programme--Photovoltaic Symposia and Information Workshops, Nairobi, Kenya, 13-18 April 1986 and Chiang Mai, Thailand, 20-25 April 1986.
- 5/ Draft report by K. Hoffman, op. cit.
- 6/ UNIDO/IS.341/Rev.2 "Directory of Solar Research Institutes in Developing Countries".
- 7/ "Solar Water Heating in Developing Countries", Swedish International Development Agency (SIDA), March 1984, quoted on page 36, "Building the renewable energy market in developing countries", Commission of the European Communities.
- 8/ GATE, questions, answers, information, September 1986, No.3/86.
- 9/ Report of the International Forum on Technological Advances and Development, ID/WG.389/6, para.71.

ANNEX I

Indicative list of research in developing countries

<u>COUNTRY</u>	<u>Suggested areas of cooperation</u>	<u>Joint research with</u>
Algeria	solar cells (incl'd. a-Si)	
Argentina	solar cells (+ a-Si) pv systems collectors solar drying energy conservation	Brazil (R+D)
CARIBBEAN	exchange of information	GATE VITA
Brazil	solar cells (MIS+SIS technology) (a-Si)	
Burundi	solar drying	USAID EEC FRG UNESCO-ANSTI Belgium (R+D, Gov.)
Cameroon	solar drying refrigeration	France (R+D)
Egypt	desert development	USAID UK (R+D) USA
Ethiopia	solar drying	ARCT
Fiji	pv solar radiation measurement refrigeration	UN Pacific Energy Programme
Ghana	solar pumping(pv) solar drying solar cookers	GTZ Togo (R+D) Benin
India	solar distillation solar drying solar cells solar cooker solar pumping , solar water heating ind. process heat desalination refrigeration flat plat collectors selective coatings sterling engine	ITDG FRG (gov) UK (R+D) IRRI (Phil) Swiss Dev.Corp. France (gov) Peru (R+D) UNU UNESCO UNFSST

Iran	desalination	
Iraq	desalination water pumping (pv) solar cells refrigeration	Jordan (R+D)
Indonesia	solar cells water pumping (thermal) pv systems solar drying solar water heater	FRG (R+D) UNFSSTD
Jordan	solar water heating flat plate collectors desalination	GTZ KISR
Kenya	solar drying	CSC (Africa Energy Programme)
Madagascar	solar cells solar thermal	France (R+D) planned: Indian Ocean countries
Malawi	solar drying solar still	
Malaysia	solar thermal solar dryers solar radiation pv solar cooling	New Energy Development Organization, Japan JILA, Japan KAIST . Korea France (gov) France (R+D) USA (commercial)
Mali		France (R+D) USA (commercial)
Mexico	water pumping (thermal + pv) concentrating collectors cooling	France (gov)
Morocco		France (R+D)
Nepal	solar water heating space heating	
Nigeria	exchange of information/visits energy conservation passive solar	

Pakistan	pv solar cell materials passive solar rural energy	USA (R+D) Turkey (R+D) ATDO
Papua New Guinea	solar drying	
China	pv solar cell design (a-Si and polycrystal) collectors solar drying solar thermal space heating water heating energy conservation desalination	
Philippines	solar grade silicon from rice husks	USAID UNDP UNESCO FRG (gov) AGSAT
Korea	pv passive solar active solar	France (commercial)
Saudi Arabia		USA (R+D) KISR
Senegal	rural energy water pumping (pv) desalination	Mali France (commercial)
Seychelles		Reunion (R+D)
Singapore	energy conservation (computer simulation) air conditioning passive solar water pumping (pv) solar ponds	GTZ USA (gov)
Sri Lanka	water heaters	

Syria	air conditioning water heating solar cells (encapsulation) pv systems selective coatings	Algeria
Tanzania	rural energy refrigeration water pumping solar cooker solar drying pv	CSC Canada (R+D) Uganda (R+D) Kenya (R+D)
Thailand	solar pond collectors (water heating) solar still rural electrification solar drying distillation	Japan (R+D)
Trinidad and Tobago		Canada (R+D) CARDI Grenada
Turkey		
Uganda		CSC: Kenya Tanzania Zambia, Malawi Zimbabwe, Mauritius Seychelles, Cyprus
Venezuela	energy conservation passive cooling simulation of thermal processes	Mexico (R+D) France (gov)
Yugoslavia	solar cells	
Zambia	solar radiation	
Zimbabwe	solar drying water heating water pumping (thermal)	

Source: Analysis of document UNIDO/IS.341/Rev.2

ANNEX II

Co-operative research suggested in:

SOLAR CELLS

Algeria
Argentina
Brazil
India
Indonesia
Madagascar
Pakistan
China
Syria
Yugoslavia

SOLAR DRYING

Argentina
Burundi
Cameroon
Ethiopia
Ghana
India
Indonesia
Kenya
Malaysia
Tanzania
Zimbabwe

PV SYSTEMS

Argentina
Fiji
Ghana (pumping)
Iraq (pumping)
Indonesia
Mexico (pumping)
Malaysia
Pakistan
China
Senegal (pumping)
Singapore
Syria
Tanzania
India (pumping)

WATER HEATING

India
Indonesia
Jordan
Nepal
China
Sri Lanka
Syria
Zimbabwe
Thailand

COLLECTORS

Argentina
India
Jordan
Mexico
China

Source: document UNIDO/IS.341/Rev.2

ANNEX III

CGIAR
DONOR CONTRIBUTIONS 1972-1981
(\$ millions)

	1972	1973	1974	1975	Actual		1978	1979	1980	Estimated 1981 ^{1/}
					1976	1977				
African Dev. Bank							.025	.030	.040	.050
Arab Fund						.310	.310		.255	.255
Asian Dev. Bank				.300		.500	-	.700	-	-
Australia		.005	1.015	1.215	1.745	1.790	2.580	2.650	2.955	3.315
Belgium	.140	.600	.380	.620	1.740	2.250	2.720	3.085	3.265	3.530
Canada	1.160	1.780	4.675	4.340	5.390	6.800	7.370	7.544	6.875	7.620
Denmark	.250	.225	.370	.400	.455	.615	.760	1.045	1.210	1.170
EEC						2.500	2.240	3.790	4.545	5.460
Ford Foundation	5.315	3.675	3.000	2.800	2.000	1.590	1.000	1.000	1.300	1.300
France			.130	.410	.510	.415	.340	.675	.855	1.095
Germany		1.805	3.040	3.935	4.475	5.350	6.760	8.475	10.100	10.000
IDB			2.030	4.120	5.000	5.700	6.185	6.200	6.700	7.400
IDRC	.175	.345	.645	.990	1.780	1.305	1.045	1.818	1.530	1.075
IFAD							-	1.550	3.570	6.570
India										.500
Iran					1.975	2.000	1.000	-	-	-
Ireland							-	-	.200	.200
Italy					.100	.030	.100	.100	.700	1.250
Japan	.105	.230	.265	.675	1.200	2.500	3.500	4.845	7.000	8.400
Kellogg Foundation	.155	.290	.280	.290	.300	.310	.320	-	-	-
Leverhulme							-	-	.490	.585
Mexico							-	-	.495	1.000
Netherlands	.375	.430	.555	1.235	1.500	1.720	1.785	2.430	2.600	3.070
New Zealand					.105	.025	.025	.025	.025	-
Nigeria				.645	.645	.620	.790	.825	1.976	1.720
Norway	.075	.185	.445	.810	1.120	1.510	1.880	1.975	1.995	2.000
OPEC Fund							-	-	.900	1.000
Philippines							-	-	.150	.500
Rockefeller Founda- tion	3.990	4.545	3.500	2.885	2.165	1.595	1.250	1.220	1.600	1.000
Saudi Arabia					1.000	1.000	-	-	-	-
Spain										.500
Sweden	1.000	.150	1.490	2.290	2.255	2.240	2.725	3.115	3.390	3.525
Switzerland		.410	.140	.460	.855	1.205	1.350	1.850	2.450	2.580
United Kingdom	.690	1.110	1.920	2.410	2.890	3.515	4.765	6.395	6.790	7.140
UNDP	.850	1.000	1.465	2.165	1.930	3.500	4.400	3.995	4.615	4.981
UNEP				.600	.340	.340	-	.150	-	-
United States	3.770	5.390	6.805	10.755	14.870	18.140	21.145	24.800	29.000	35.000
World Bank	1.260	2.780	2.375	3.195	6.525	7.850	8.675	10.200	12.000	14.600
Others										
Kresge		.750								
TOTAL	20.060	24.955	34.525	47.545	62.870	77.225	85.045	99.487	119.576	138.391

Source: Centers' Program and Budget Papers and accounts, 1974-1981.

1/ Contributions as pledged November 1980. Values will vary depending on date of disbursement.

September 1981

ANNEX IV

CGIAR: Donor contributions to center programs, 1972-85 (in US\$ million).

Donor	Core Programs						Total (Core + Non-core)		
	1972-76	1977-81	1982	1983	1984	1985	1983	1984	1985
Australia	4.00	13.28	3.77	4.06	4.00	4.18	4.11	4.03	4.27
Belgium	3.48	13.70	1.85	1.88	1.71	2.01	2.46	2.31	2.66
Brazil	—	—	—	—	1.00	—	—	1.00	—
Canada	17.37	36.14	8.29	9.94	10.03	9.70	10.74	11.58	12.74
China	—	—	—	—	0.50	0.50	—	0.50	0.50
Denmark	1.71	4.69	0.96	0.95	1.24	1.12	0.95	1.24	1.26
Finland	—	—	—	—	0.50	0.60	—	0.50	0.60
France	1.05	3.14	0.90	1.01	0.88	1.23	1.10	0.94	1.39
Germany, Fed. Rep.	13.27	39.06	7.84	7.89	6.67	6.15	8.68	7.39	8.14
India	—	0.50	0.50	0.50	0.50	0.49	0.50	0.50	0.49
Iran	1.98	3.00	—	—	—	—	—	—	—
Ireland	—	0.38	0.21	0.34	0.41	0.40	0.34	0.41	0.40
Italy	0.10	1.90	1.59	6.10	6.62	6.49	6.10	6.62	6.78
Japan	2.49	26.25	8.85	9.13	9.72	11.09	9.48	10.46	12.05
Mexico	—	1.45	0.10	0.15	1.22	0.37	0.15	1.44	0.47
Netherlands	4.11	11.54	3.24	3.58	3.28	3.89	4.12	3.79	4.53
New Zealand	0.11	0.14	0.02	0.02	0.02	0.01	0.02	0.02	0.01
Nigeria	1.30	5.36	1.13	1.00	1.00	0.85	1.40	1.60	1.29
Norway	3.33	9.27	1.87	2.19	1.92	2.27	2.19	1.92	2.27
Philippines	—	0.85	0.45	0.35	0.32	0.23	0.35	0.32	0.23
Saudi Arabia	1.00	1.00	—	1.50	1.50	—	1.50	1.50	—
Spain	—	0.50	0.46	0.52	0.52	0.50	0.52	0.52	0.50
Sweden	7.19	14.80	3.18	3.05	3.07	3.02	3.05	3.07	3.02
Switzerland	1.87	9.47	2.76	4.89	6.70	5.17	5.91	8.21	7.80
United Kingdom	9.02	27.51	6.34	5.92	5.66	6.32	5.98	5.74	6.33
United States	41.60	128.09	40.79	44.55	45.25	45.16	55.02	56.85	60.19
Country Subtotal	114.98	351.82	95.11	109.52	114.23	111.74	124.67	132.46	137.90
Ford	16.79	6.20	0.81	1.31	0.99	0.90	1.75	1.37	1.68
Kellogg	1.32	0.63	—	0.63	0.34	—	0.69	0.41	—
Kresge	0.75	—	—	—	—	—	—	—	—
Leverhulme	—	1.08	0.65	0.75	0.81	0.60	0.75	0.81	0.60
Rockefeller	17.10	6.67	0.80	0.50	0.50	0.80	0.54	0.55	0.99
Foundation Subtotal	35.96	14.58	2.26	3.19	2.64	2.30	3.72	3.14	3.27
ADB	0.30	1.20	—	—	—	—	0.17	0.45	0.64
AFDB	—	0.15	0.02	—	—	—	—	—	—
AFESD	—	1.12	0.24	0.23	0.23	0.34	0.23	0.23	0.34
EC	—	17.36	4.72	5.16	4.72	6.58	6.25	6.01	7.95
IDB	11.15	32.19	8.10	8.16	8.73	8.17	8.16	8.73	8.17
IDRC	3.95	5.68	1.20	1.80	1.01	1.30	2.45	2.78	3.12
IFAD	—	11.05	5.94	8.37	7.02	3.15	10.31	8.67	5.26
OPEC	—	1.90	3.58	2.25	2.19	1.00	2.25	2.19	1.05
UNDP	7.42	21.59	6.19	6.86	8.06	7.49	7.16	9.12	8.85
UNEP	0.94	0.49	0.18	0.13	0.03	—	0.17	0.03	0.02
WORLD BANK (IBRD)	16.15	53.33	16.30	19.00	24.30	28.10	19.50	24.68	28.87
International Donor Subtotal	39.91	146.08	46.47	51.96	56.29	56.13	56.65	62.88	64.27
Other Donors	—	—	—	—	—	—	3.29	4.60	4.37
TOTAL	190.85	512.48	143.84	164.67	173.16	170.17	188.33	203.08	209.81

Source: CGIAR 1985 Annual Report



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Workshop on the Establishment of a
Consultative Group on Solar Energy
Research and Applications (COSERA)

Vienna, Austria, 8-10 December 1986

STATE OF THE ART
OF
RESEARCH AND DEVELOPMENT OF SOLAR ENERGY
TECHNOLOGIES IN INDIA*

Prepared by

T. K. Moulik**

* The views expressed in this document are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. The document has been reproduced without formal editing.

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Introduction

In India, Solar Energy was first harnessed during the early fifties, but did not gain much impetus. During recent years, increasing attention has been diverted towards renewable sources due to the sharp increase in oil prices, difficulties in producing and transporting increasing amounts of fossil fuels, supply uncertainties and environmental degradation caused by conventional fuels.

Solar energy is a major focus of non-conventional energy sources. It has applications in all sectors and is capable of supplementing existing sources of energy. It plays a pivotal role and has long been a part of the Indian way of life.

A number of reputed national institutions are involved in doing research and putting up field demonstration units to popularize non-conventional sources of energy.

The Commission for Additional Sources of Energy has taken up projects for the establishment of production facilities for solar cells, solar thermal systems and various other renewable energy devices. Today, India is capable of making solar photovoltaic devices and systems, solar water heating systems, solar crop dryers, solar stills, etc.

In spite of all this, there is a great need to build up a countrywide infrastructure for production, distribution, sales and servicing of renewable energy systems and also to promote awareness of the role and potential of renewable energies and the importance of energy conservation.

The present paper highlights the importance of renewable energy sources by cataloguing various research investigations and field and demonstration trials which in their turn have created public awareness regarding these renewable energy sources.

Economic and Financial Constraints

- One of the most important constraints in the wider utilization of renewable energy sources is the high initial cost of the systems. At present, a solar device may cost more than a product based on conventional fuel. This acts as a deterrent to the potential users of renewable energy systems. On the other hand, the low level of production inhibits any cost reduction. This has become a vicious circle.
- These problems can only be overcome through technical improvement material and manufacturing development and a package of fiscal and other promotional measures.
- Incentives and subsidies introduced at the initial stages will help the new and renewable sources to become economically competitive.

Research and Development of Solar Thermal Energy

Despite various incentives and subsidies, the renewable energy sources have not been fully exploited. Thus, it would be desirable to concentrate on ways and means of minimizing the use of conventional energy by supplementing it with new and renewable sources of energy.

The Department of Non-Conventional Energy Sources has promoted and funded research and development activities in the area of Solar Thermal Conversion through various Universities, National Laboratories, with a view to developing newer materials and efficient systems and devices, improving reliability and performance of the systems and reducing costs. These research and developmental efforts include collection of basic meteorological data like isolation, wind velocity, rainfall, relative humidity at various locations in the country which are the key factors for effective utilization of solar energy.

The thrust areas, in solar thermal energy conversion, include development of materials for efficient collector system, development of advanced collectors for medium temperature and high temperature output, development of solar refrigeration, air-conditioning systems, development of heat storage system and studies on systems engineering.

The Seventh-Five Year Plan document has outlined the importance of research and demonstration and field trials in creating public awareness towards renewable energy sources.

The Advisory Board on Energy has suggested that besides increasing the R&D efforts, a large number of systems may be installed through the demonstration programme as well as the extension programme of private users on a cost-sharing basis. The Board has also recommended that the facilities for soft loan finance may be provided for users of such systems. The Government has recently introduced additional subsidies and incentives for the promotion of Solar Thermal Systems. Hundred per cent subsidy is now available for installation of Solar Thermal Systems on public buildings where the cost of conventional fuel and energy is paid from the Consolidated Fund of India. This has aroused considerable interest from various public and private industries and establishments like hotels, textiles, hospitals, etc. With this it is hoped that the Solar thermal programme will pick up and assume unprecedented proportions.

The overall objective of the Solar Thermal Programme is to develop systems through R&D activities, put up field demonstration units to collect performance data under actual field conditions and later on commercialize the systems for large scale utilization through an extension programme.

Work has been carried out in Institutions like

- *National Physical Laboratory, New Delhi;
- *Central Salt and Marine Chemicals Research Institute, Bhavnagar;
- *Central Building Research Institute, Roorkee
- *Central Arid Zone Research Institute, Jodhpur

on various problems including water heating, distillation, drying, cooling and space heating since early sixties but the work was scattered and sporadic.

At present the industrial organisations participating in the R&D activities are

- Bharat Heavy Electricals Limited
- Central Electronics Limited
- Tungabhadra Steel Products Limited
- National Instruments Limited and

several other firms in the private sector.

Solar Water Heating Systems

They have become popular due to various technical and fiscal promotional measures. 460 solar water heating systems with a total capacity of 11,71,303 litres per day and approximately 24,147 m² collector area have been installed, upto now.

- Two solar water heating systems of capacity 54,000 lpd with 1082m² of collector area were installed at Bhopal dairy, Madhya Pradesh, and
- Capacity 48,000 lpd with 1000m² collector area at Erode Textile Mills, Tamil Nadu.
- Solar Water Heating System of Capacity 2,000 lpd was installed at Air Force Missile School and Centre, Gopalpur on Sea, in Orissa.
- Another system of 2000 lpd at 65°C was installed at the Hindustan Organic Chemicals Ltd; Raxayari, Bombay. The hot water is being utilized for dissolution of sodium sulphite to be used in manufacturing operations of Meta Dinitrobenzene.
- Another system of capacity 2000 lpd was installed at Beggar Home, Delhi. Such a facility for poor people has been provided for the first time in the country.
- Four solar water heating systems of total capacity 1,76,000 lpd at 85°C with the collector area of 5614m² have been generated for Ordnance Factory, Itanagar, Madhya Pradesh.

*Solar Water heating system was installed for 68 quarters of Indo-Tibetan Border Police in Leh.

*Solar heating, cooling and hot water system was installed in the DNES building.

*Two solar water heating systems installed at Parag Dairy, Kanpur with (1) capacity of 50000 l/day to heat water to a temperature of 60°C; (2) capacity of 20000 l/day to heat water to a temperature of 85°C.

Solar Crop Dryers

*A pilot plant for tea drying was installed at Tocklai Tea Research Station, Jorhat in Assam.

*A 10-tonne per day grain drier has been installed in Ludhiana.

*A 30-tonne per day grain drier is installed at Allathur.

*Optimisation of Solar drying system for agricultural produce (in collaboration with the Colorado State University USA) Annamalai University.

*A wool drying plant was installed at Kambal Kendra, KVIB, Gwalior, Madhya Pradesh.

*Investigation of Solar Drying of Fish for Food and Feed, Indian Institute of Technology, Kharagpur.

*Utilization of Solar Energy for drying of Agricultural and food materials in improved solar dryers, Jadavpur University, Calcutta.

*Solar drying of Kendu Leaves; Science Technology and Environment Department; Orissa Government.

*Almost 30 solar kilns for drying timber with capacity of 7 cubic metres to 18 cubic metres have been installed in a few places and have shown promising results.

Solar Thermal Power Generation

- *Development of a thermal storage system suitable for solar thermoelectric and total energy systems was installed Phase II - SHEL, Hyderabad.
- *Effect on interstitial pressure and temperature on thermal conduction through porous and dispersed system and its application to solar thermal storage; University of Rajasthan, Jaipur.
- *Test facilities for solar collector, NPL, New Delhi.
- *Design, development and testing of paraboloid dish collector, SHEL, Hyderabad.
- *Development, Optimisation and Study of solar thermal system using the linear solar concentrator, Indian Institute of Technology, New Delhi.
- *Demonstration of a solar thermal power generation system for remote rural area, Jyoti Solar Energy Institute, Vallabh Vidyanagar, Kaira, Gujarat.
- *Setting up of salt gradient solar pond for the dairy plant at Jamnagar for supplying of process heat for hot water and power generation design (Phase 1), GEDA, Vadodara and Gujarat Dairy Development Corporation, Gandhinagar.
- *Proposal for development of a micro computer model of thermal behaviour of buildings, TRI, New Delhi.
- *Status report with a view to designing standards for testing of Solar Thermal Devices, Indian Institute of Technology, Delhi.

Concentrating and Advanced Collectors

- *For generating steam and providing heat in temperature range of 100-300°C, parabolic trough concentrating collectors with one axis tracking have been developed through an Indo-US Aid project.
- *System for generating steam for use in a Silk factory in Mysore is under installation.

*Design, development, fabrication and testing of vacuum tube collectors. Phase II School of Energy Study, University of Poona, Pune.

*Installation of TAP collector for passive heating system and for ITSP quarters at Leh. Central Division, DPWD, Srinagar.

*Demonstration and development of low cost plastic solar collectors for air and water heating. Phase II, Indian Institute of Technology, Delhi.

*Three ton solar powered refrigeration plant for sub zero operating temperature, Vallabh Vidyanagar District, Kaira, Gujarat.

*Design, development and testing of a paraboloid dish collector, BMEL, Hyderabad.

Solar Cookers

The programme for manufacture and subsidised sale of solar cookers was launched in November 1981. So far about 46,000 solar cookers have been sold. Sales are executed through agencies designated by the respective state governments.

*Preparation of solar cooker status report, CEDA, Baroda.

*A Study on the performance of the Solar Cookers, MS University, Baroda.

*Design and Development of inexpensive solar cookers for application both in rural and urban houses, CES, IIT, Delhi.

*Comparative studies on the Nutritive value of the Food Using Solar and other fuels for cooking. Shri Parashakti College for Women, Courtallam.

Solar Refrigeration and Cooling

- *Design and development of optimal continuous solar absorption refrigeration and air-conditioning systems (with James Cook University of North Queensland, Australia under Indo-Australia Programme of SAT, IIT Madras.
- *Installation of a solarwater chiller at Delhi Public School, RK Puram, New Delhi, SEC, New Delhi.

Other R&D Projects

- *Project to survey alternative energy sources in the Kumaon hills, Department of Physics, DSB University, Nainital.
- *Pilot plant for extraction of ethyl Alcohol from Fermented Sweet Sorghum Juice by Solar Energy, Nimbkar Agricultural Research Institute, Phaltan.
- *Development of solar dehydration system for field trials for dehydration of grapes to produce resin. University of Poona, Pune.
- *Solar Desalination, IIT, Delhi.
- *Augmentation of network of radiation stations of India, IMD, New Delhi.
- *Study of the efficiency of the use of renewable source of energy in tea processing, NIDC, New Delhi.

Use of Solar Energy for Dairy Development

In order to promote the agricultural allied and ancilliary activities during the 1970's assistance was extended to small and marginal farmers and also agricultural labourers to purchase milch cattle. The purchase under the SFDA, and MFAL schemes was heavily subsidised. Apart from these incentives, the Government has also attempted to introduce solar energy to improve the dairy units efficiency. A number of demonstration

programmes have been launched by the Department of Science and Technology.

These solar installations propose to save a substantial amount of conventional fuel and to improve the profitability of the dairy units.

Parag Dairy at Kanpur has installed two solar water heating systems:

- 1 First of the capacity of 30000 l/day to heat water to a temperature of 60° C.
- 2 Second of the capacity of 20000 l/day to heat water to a temperature of 85°C.

Water heated to 60°C is used for washing and cleaning utensils, and the latter will be used as a boiler feed.

Solar Energy Centre

This Centre has been established to promote applications of solar technologies, through product development, systems engineering and development, testing and certification of materials, field demonstration testing and certification of solar components and systems, material components, product and system standardisation, arranging training courses and seminars and providing the necessary links between R&D organisations and Industries within and outside the country.

At present the Centre is functioning in a shed in District Gurgaon, Haryana. The permanent facilities for the Centre are being set up at Gwalpahari District, Gurgaon, but it is still under construction.

Solar Photovoltaic Systems

The concept of producing electricity directly from sunlight without the intermediate transformation to heat and mechanical energy is based on the "photovoltaic" effect. It has great potential in India where there is plenty of sun and a great need for electrical energy for decentralised applications. These systems are particularly suited for various rural applications as they provide for on-site generation of electricity. Various photovoltaic systems include - water pumpsets for micro-irrigation and drinking water supply, radio beacons for ship navigation at ports, community radio and television, cathodic protection of oil pipelines, weather monitoring, railway signalling equipment, battery charging etc.

The present cost of photovoltaics being fabricated in India is about Rs 100/- per peak watt. It is estimated that at a cost of about Rs 40 per peak watt, solar photovoltaic water pumping systems would become cost effective in comparison to the present day diesel pumpsets. Though initial costs are considered high compared to other systems based on conventional energy sources, they are competitive at current prices in certain remote areas which are not served by electric grids, where it is difficult to transport conventional fuels, and where power in small capacities is required.

The scope for utilization of these devices will increase with reduction in prices through technology development and increased production. India is one of the few countries in the world to have developed productive capability based on indigenous technique.

The PV Devices are portable, require no fuel, offer a pollution free source of power, they are easy to operate, maintenance free, have long effective life and are extremely reliable. These features make PV systems most suitable for installation in remote and isolated areas, forest and hilly areas and desert locations.

Research and Development

During the sixth five year plan, a comprehensive programme of research and development, pilot production and demonstration were implemented. This programme led to the development of indigenous technology for production, creation of initial infrastructure for the manufacture, installation and maintenance of photovoltaic systems and promoted awareness among potential users. These activities have been further diversified and expanded in the Seventh Five Year Plan.

*Silicon in different forms is the primary material used for solar cell production. Some projects relating to casting and directional solidification of silicon have been completed.

*An integrated programme on amorphous silicon solar cells has made steady progress. Plasma deposition facilities for experimental work have been established at Indian Association for Cultivation of Science, Calcutta, IIT, Delhi and University of Poona. New equipment has been ordered by National Physical Laboratory. Silane gas which is an essential input to amorphous silicon production has been produced in small quantities at IIT, Kharagpur and IISc. Bangalore and is being tested for its quality.

*Amorphous Silicon solar cell technology has also been identified as one of the Science and Technology Missions in the Seventh Plan. The DNES has proposed to set up a pilot plant for making amorphous silicon solar cells and modules. A preliminary project document has been prepared and forwarded to UNDP for possible assistance regarding the equipment not made in India.

*Research on other aspects of PV technology like photoelectrochemical solar cells, thin film devices based on compound semiconductor materials such as copper indium diselenide on implantations and laser annealing, system development etc. are also being supported.

*The R&D programme also covers testing and evaluation of deep-well pumps and medical refrigerators. Import of photovoltaic modules from 7 foreign manufacturers is being arranged for purpose of evaluation and trial in Indian conditions.

NASPED Programme

A five-year National Solar Photovoltaic Energy Demonstration (NASPED) programme was sponsored by the Department of Non-Conventional Energy Sources at the Central Electronics Ltd. Sahibabad from October 1980. The main objectives of the programme were the establishment of pilot production facilities for solar cells and modules and the development and demonstration of PV systems for various applications. The pilot production has led to the establishment of production facilities on commercial lines. The achievements of the programme are as follows:

- Technology for solar cells and module production was developed from bench scale to commercial scale production.
- Variety of systems have been designed, developed and field tested which include water pumping systems for drinking water supply and micro irrigation, street lighting units, community lighting systems, community TV etc.

- The programme has helped to create a pool of technical manpower capable of technology development, systems engineering, production management.
- A total of 401 systems were supplied under the NASPED programme between April and September 1985. These included 246 pole-mounted street lighting units, 47 water pumping systems and 101 TV systems.

Demonstration Activities

There has been a significant rise in the demonstration activities. The following are the highlights of these activities:

1 Village Electrification

After the successful demonstration of photovoltaic powered street lighting units Salojipally village in Andhra Pradesh and five other villages in Tamil Nadu more installation of street lighting units in village Orcha in the Bastar District of Madhya Pradesh were arranged.

A programme for installation of solar powered street lights in 250 villages was taken up during 1984-85 through the Rural Electrification Corporation, State Electricity Boards, and Nodal Agencies of some of the State Governments.

2 Centralised PV Systems

A central PV power system has been installed in the Village Achheja in Gaziabad district of UP to provide power for about 30 street lights and community TV and radio sets. A PV water pumping system has also been installed. An experimental programme is also being taken up in co-operation with Rural Electrification Corporation in respect of 4 villages.

3 Water Pumping Systems

A special project for the demonstration and popularisation of solar photovoltaic water pumping systems was taken up in the States of Andhra Pradesh, Bihar, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal by a recommendation made by the Advisory Board on Energy. This programme of demonstration and field trial is being expanded and arrangements are being made for the supply of 300 pumping sets.

4 Community TV Sets

A total of 200 PV powered direct reception sets are being installed by Doordarshan in Uttar Pradesh and Bihar. The PV power packs for these systems have been supplied with the support and sponsorship of DNES. These systems enable uninterrupted viewing of TV broadcasts received directly from INSAT-1B.

Industrial Production

DNES is responsible for regulating the industrial and import licensing of solar photovoltaic devices.

- During the year Central Electronics Ltd. (CEL) has installed new equipment for production of modules and cells and is expected to achieve a total cell production capacity of 2 MW and module production capacity of 1.35 MW by March 1986. Lamination technology has been introduced into production. The production at CEL between April and December 1985 amounted to 243 MW. The production at BHEL during the same period was approximately 70 Kwp.

Rajasthan Electronics and Instruments Ltd. has also commenced production.

- Both CEL and BHEL make supplies for photovoltaic systems for specialised applications like telemetry power supplies for off-shore oil platforms and communications.

The systems supplied by CEL and BHEL during the year 1985-86 are as follows:

System	CEL	BHEL
Water Pumping Systems	69	35
TV and TV-cum-Lighting Systems	212	1
Community Lighting Systems	7	-
Street Lighting Units	637	338
Systems for off-shore oil platforms	-	6
Modules for Battery charging units	300	300
Other Systems	27	1

A BHEL-made PV system for battery charging has been successfully used by the Indian Expedition to Antarctica in 1985-86.

Annex I

List of R&D projects supported by DNES in the year 1985-86

Title of the Project

Institution

Crystalline and Poly-Crystalline Silicon
(Material/Device)

- | | |
|--|--------------------------|
| • Production of Solar Grade Silicon by hot metal Solvent extraction and directional solidification | RRI, Bhubaneswar |
| • Studies on Poly-Crystalline Silicon for photo-voltaic Solar Energy Conversion - Phase II | NPL, New Delhi |
| • Electrowinning of High purity, low cost Silicon suitable for Solar Cell Devices | Anna University, Madras. |
| • Polycrystalline Silicon from Rice-Husk | IIT, Kharagpur. |

Amorphous Silicon Solar Cells

- | | |
|--|----------------------------|
| • Development of Amorphous Silicon thin film solar cells. | IACS, Calcutta. |
| • Research, Development and Production of Amorphous Silicon Solar Cells | University of Poona, Pune. |
| • Development of Amorphous Silicon Solar Cells | IIT, New Delhi |
| • Development of the techniques for production operation and storage of silanes from rice husk for preparing a-si. | IIT, Kharagpur |
| • Production of Silanes for amorphous silicon and polysilicon applications. | IISc., Bangalore. |
| • Amorphous Silicon Solar Cells - Development and Evaluation Studies. | IIT, Madras. |
| • Investigation on hydrogenated Amorphous Silicon films. | NPL, New Delhi. |

Photoelectrochemical Cells

- Photoelectrochemical conversion and storage of Solar Energy. BHU, Varanasi
- Photoelectrochemical Solar cells using transition Metal Dichalcogenide Crystals. Sardar Patel Univ., Vallabh Vidyanagar
- Solar Energy Conversion using Narrow Bandgap semiconductor Electrodes in Photoelectrochemical cells. Gorakhpur Univ., Gorakhpur.
- Solar Energy Conversion through photoelectrochemical systems. IISc. Bangalore.
- Studies in photochemical conversion of Solar Energy. MLS University, Udaipur.
- Energy conversion in Photoelectrochemical systems. IIT, Delhi.
- Photoelectrochemical Energy Conversion. IIT, Delhi.

Photovoltaic Systems

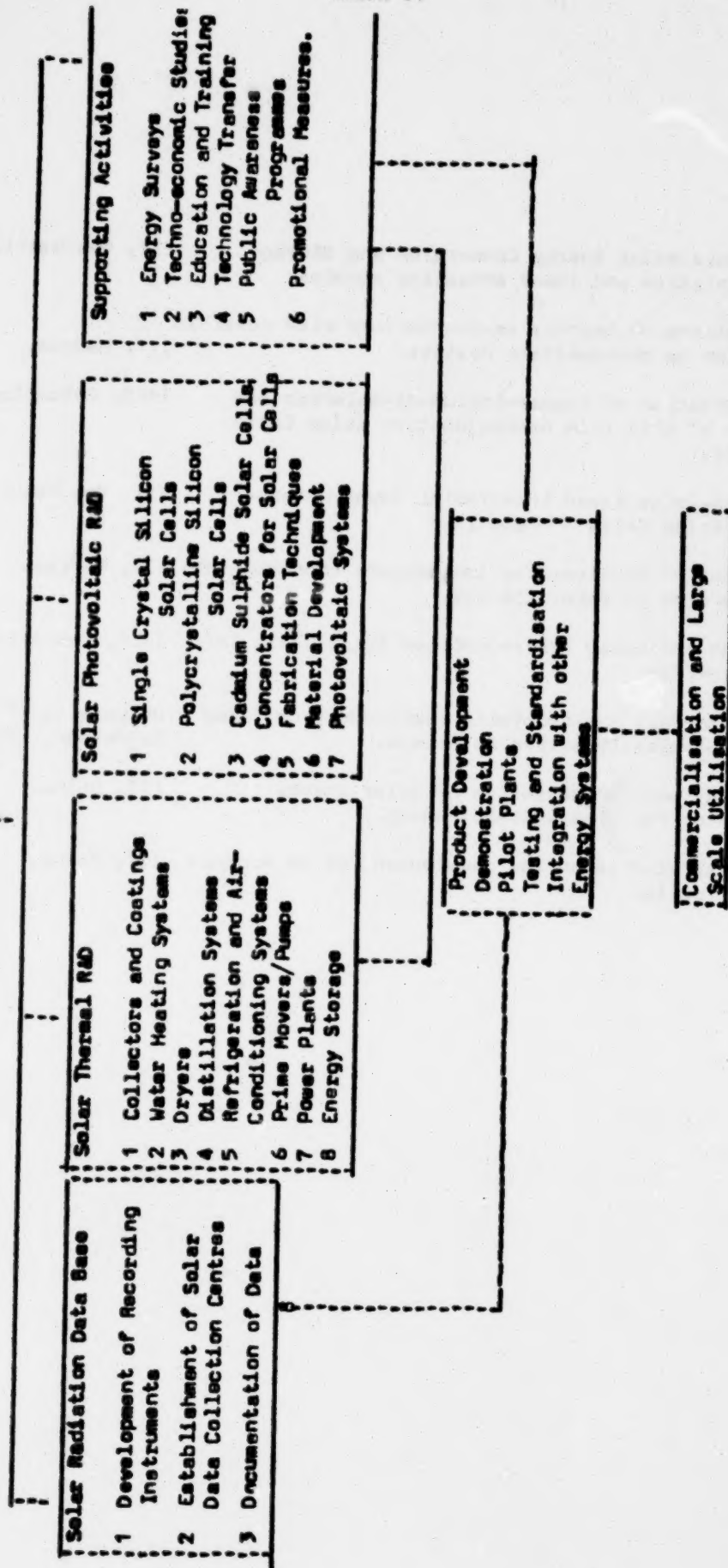
- Development and Demonstration of Concentrator Photovoltaic Systems for specific stand alone rural applications. Kalyani University, Kalyani.
- Photovoltaic solar Electric Power for Rural Development in Sunderban Bidhan Chandra Krishi Vishwa Vidyalay, Kalyani.

Other Projects

- Development of thermoelectric generators for Solar (and other) energy conversion - Phase II IIT, Kharagpur.
- Study on large area Semiconductor liquid junction Photovoltaic Cells. Shivaji University, Kolhapur.

- Photovoltaic Solar Energy Conversion and Storage ion implantation and laser annealing studies. IIT, New Delhi.
- Investigations on ternary semiconductors with possible application as photovoltaic devices. IIT, Madras.
- Characterization of Copper-Indium-Ci-Selenide and formation of thin film heterojunction Solar Cells: Cds/CuInSE . IACS, Calcutta.
- Indium-Tin-Oxide based interfacial layer Heterojunction Solar Cells - Phase II. IIT, New Delhi.
- Development of Non-tracking luminescent concentrators for Conversion of Solar Energy. IIT, Madras.
- Studies on InP based heterojunction Solar Cells InP/ITO and InP/Cds. IACS, Calcutta.
- Study of Ternary chalcophyrite semiconducting films as photovoltaically active materials. University of Rajasthan, Jaipur.
- Development and demonstration of solar energy concentrator for Photovoltaic Panels. IIT, Delhi.
- Feasibility studies on the development of an organic dye solar cells. IIT, Delhi.

INTEGRATED SOLAR ENERGY PROGRAMME





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SOLAR ENERGY IN LATIN AMERICA

Prepared by

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I. INTRODUCTION

The present author's experience concerns mainly the photovoltaic conversion of solar energy. Consequently this contribution refers essentially to this field. However a few words concerning solar thermal conversion research and applications will help to judge its importance.

There is a considerable activity in solar thermal conversion in Latin America. Almost all types of technologies are being investigated by more than a hundred groups of variable size and experience. A good idea of these activities can be obtained from the proceedings of the 5th Latin American Congress on Solar Energy, held in Valparaiso, Chile, October 1986. Solar thermal collectors for water heating at domestic level are used in almost all Latin American countries. These collectors are manufactured by more than a hundred local companies of variable size. Nevertheless many of them experience commercial difficulties due to: i) a lack of strong official backing programmes for the use of solar energy (either at a residential level or at an industrial one) and ii) insufficient mature technology. A special programme for the appraisal of the problem is recommended.

Photovoltaic (PV) technology is by origin strongly related to the semiconductor electronic industry. In both cases research and development experience a difficult start in most developing countries where well trained people and specialists are seldom existent.

The analysis of the research activities in Latin American universities and research institutions, where most of the existing work is being done, shows that in many of them exists a deficient scientific leadership. Researchers, students and technicians are in general highly motivated and hard working people, the full

potential of which is not being used because of the abovementioned limitation and by the lack of clearly established sound research objectives.

Once the main investment in laboratory equipment has been made, the group faces a heavy bureaucracy for importing spare parts, special gases, chemical reagents and similar inexpensive and fundamental items. These cumbersome bureaucratic procedures tend to discourage the researchers and to break the necessary continuity of the research effort. The result of this situation is that the scientific output/input ratio is low for the Region, i.e. the scientific production as measured by international publications, patents, technical reports, etc., is not commensurate to the investments in research facilities and salaries.

Whithin this context the importance of both, human resources formation and the existence of dynamic purchasing mechanisms become clear. Meanwhile it is the author's opinion that the availability of PV specialists and trained technicians is the key issue for the future of photovoltaics in Latin America.

At present, investment in solar industry is not good business not only in developing countries but in advanced countries as well. Meanwhile it is also true that an industrial effort should be made if the future energy needs of mankind are to be satisfied. In industrialized countries solar PV programmes were established soon after the first oil crisis, their common characteristic being a strong government backing in the form of subsidies and markets for the production of this infant industry. These national programmes do not exist in Latin American countries. The necessity appears for the establishment of clear PV application programmes at national and regional level that will encourage productive activities in the field as well as the identification of the local energy problems that might be solved through the use of solar PV.

II. PV RESEARCH AND DEVELOPMENT ACTIVITIES:

The following description is certainly not exhaustive. It is based on personal contacts, visits to laboratories in different countries and the analysis of publications and contributions to international and regional PV conferences. Anyhow it represents a rather good description of the main activities being held in the Region. Research groups working on photovoltaic materials and devices exist in: Brazil, Mexico, Argentina, Colombia, Venezuela and Cuba.

BRAZIL

1. Laboratory of Photovoltaic Conversion, Institute of Physics, Campinas State University (UNICAMP), Campinas, SP.

This research group started their PV activities in Brazil in 1979. By its size and experience it/^{is} the most important research group in advanced PV materials and technologies in Latin America. The group has developed technologies on single crystal solar cells, MIS silicon solar cells and amorphous p-i-n solar cells. The main research activities refer to amorphous materials of photovoltaic interest: a-Si:H, a-Si_{1-x}C_x:H, a-SiN_x:H, a-Si_{1-x}Ge_x:H, a-GeN_x:H and transparent electrodes: SnO₂, Indium Tin Oxide, etc. In the last five years the Laboratory produced more than 25 scientific international publications, 50 communications and a dozen technical reports. Other important fields of work are: polycrystalline solar cells from up-graded metallurgical silicon, modelization of crystalline and amorphous solar cells and socio-economic aspects of solar energy conversion. The group is composed of five senior researchers, eight post-graduate students and three technicians. It has strong scientific relations with American and European laboratories and cooperates with other research groups in Argentina, Colombia and Brazil.

2. Microelectronic Laboratory, Polytechnic School, University of São Paulo, S.P.

The group started their activities in 1981 and is more engineering oriented. The main research activities are in single crystal, polycrystalline and amorphous silicon cells, as well as in transparent electrodes. One senior researcher and ten post graduate students, engineers and technicians comprise the team. The group has close contacts with other Brazilian research groups and with the University of Lisbon in Portugal. Several publications of international level have been produced in the last years.

3. Department of Metallurgy, COPPE, University of Rio de Janeiro, R.J.

The PV activities of this group started some four years ago and essentially refer to the study of surfaces and interfaces of amorphous materials and devices. The team perform research on the properties of a-Si:H and on the formation of silicides onto a-Si:H films. One senior researcher and half a dozen junior researchers and post-graduate students carry out this activity in strong interaction with well known German research laboratories and Brazilian groups. Their activities are more oriented to materials science than to PV devices.

4. Department of Metallurgy, Engineering Military Institute, Rio de Janeiro, R.J.

This group started as a thin film research group more than ten years ago. It is composed of one senior researcher and nearly half a dozen post-graduate students and technicians. The main activity up to now has been the study of II-VI semiconductor compounds and devices. Recently some research activities on InP have been performed.

5. Department of Physics, Fluminense State University, Niteroi, R.J.

The research activity related to photovoltaics consists of theoretical work on the electronic structure of a-Si:H and amorphous silicon alloys performed by two senior researchers. They work in close cooperation with the PV Conversion Lab. of UNICAMP.

6. Faculty of Engineering, Pernambuco State University, Recife, Pe.

A small team exists performing PV engineering work on systems and concentrators.

MEXICO

1. Department of Electrical Engineering, Center for Advanced Studies, National Polytechnic Institute, Mexico City, D.F.

This is probably the oldest photovoltaic group in Latin America. Their activities started at the end of the sixties and have been oriented towards the development of single crystal and polycrystalline silicon solar cell technology. A small crystalline silicon solar cell manufacturing pilot plant was established five years ago and the PV modules produced there are used to power stand-alone systems in isolated villages (mainly for illumination and communication systems). Research work on CdS, chemically sprayed SnO₂, hydrogenation effects on polycrystalline silicon solar cells and GaAs epi-layers grown by close spaced vapor transport have been made. Some solar cell modeling work is also done and recently an a-Si:H program has started. The size of the research team varied over time but was normally composed of three senior researchers and half a dozen engineers and technicians working at the pilot plant. Three to four graduate students work for their MSc or PhD degree in activities related to PV.

2. Department of Physics, Center for Advanced Studies, National Polytechnic Institute, Mexico City, D.F.

During the last years some experimental research on CdTe has been performed.

3. Institute for Materials Research, National Autonomous University, Mexico City, D.F.

A small research group on Si:H films and devices started their activities a few years ago. Some economic studies on PV applications have also been made as well as theoretical studies on the electronic structure and vibrational properties of amorphous semiconductors. Recently the group split into two parts, one of them moving to Temixco, near Mexico City where a new Solar Energy Research Institute has been established. Approximately twelve researchers and students are working in both groups.

ARGENTINA

1. National Institute for Chemical Technology, Santa Fe.

A research team oriented towards PV materials and devices started their activities five years ago with pretty good research facilities. Some work has been done on a-Si:H films produced by D.C. magnetron sputtering. There is also some theoretical work being done on the electronic structure of and defects in a-Si:H as well as on the modelization of polycrystalline/ amorphous silicon heterojunction. Recently the group started a glow discharge-produced a-Si:H programme in cooperation with the Photovoltaic Conversion Laboratory, Unicamp, Brazil. The group size is about six researchers and students.

2. Atomic Energy Commission, Buenos Aires.

A project for the establishment of a crystalline silicon solar cell production plan involves six researchers and engineers. They are involved with the engineering aspects of solar cell production. The project received some support from UN but it is still in a preliminary stage.

COLOMBIA

1. Department of Physics, National University, Bogota.

Research work on $\text{Cu}_2\text{S}/(\text{ZnCd})\text{S}$ Solar Cells. Group size unknown.

2. Department of Physics, Del Valle University, Cali.

A small research group^{is} starting activities in a-Si:H film deposition and characterization in cooperation with the Photovoltaic Conversion Laboratory of Unicamp, Brazil. Group size; five researchers and students.

VENEZUELA

1. Simon Bolivar University, Caracas.

Studies on spray pyrolyzed ZnO and also on CdS/CdTe heterojunctions. Group size and composition unknown.

2. Venezuelan Institute of Scientific Research, Caracas.

Material science group working for several years on ternary and quaternary semiconductors compounds of photovoltaic interest. Present group size unknown.

CUBA

1. Institute for Technical Research (ININTEF), Habana.

Some PV activity exists in this institution on concentrators for silicon solar cells. No information available on group size and other activities.

III. INDUSTRIAL PV ACTIVITIES

Apart from the already mentioned pilot plant manufacturing crystalline solar cells in the National Polytechnic Institute in Mexico there are two other industrial photovoltaic activities, one in Brazil and one in Argentina.

BRAZIL - Heliodinâmica S.A.

Heliodinâmica represents one of the most important industrial activity in photovoltaics in the Third World.

Established in 1980 the company manufactures, with Brazilian technology, single crystal silicon ingots and wafers, crystalline silicon solar cells, PV modules and systems.

1. Silicon ingots (Czochralski method, up to 8" diameter) full production capacity: 34 tons/years.
2. Silicon wafers (unpolished, up to 8" diameter) full production capacity: 1.2 million wafers/year.
3. Silicon wafers (polished, up to 6" diameter) full production capacity: 150.000 wafers/year.
4. Photovoltaic cells and modules (4" diameter cells) full production capacity: 1 MWp/year.

The company is currently exporting silicon wafers to the USA, Argentina, India and other countries. To a lesser extent Heliodinâmica exports also solar cells, PV modules and systems.

In a recent study financed by the World Bank and performed by Halcrow and Partners on the performance of commercial PV water pumping systems, Heliodinâmica and a Danish company were, out of 62 international manufacturers, the only two that satisfied the quality requirements imposed by the Bank.

ARGENTINA - Solartec S.A.

At present Solartec is encapsulating silicon solar cells from Heliodinâmica, Brazil, within a technology transfer agreement that foresees the fabrication in Argentina of PV modules and systems with (partially) Brazilian technology.

IV. COOPERATION PROGRAMMES AND RECOMMENDATIONS.

As already pointed out there exists a great diversity of situations concerning photovoltaic R&D in Latin American countries . Consequently, the policies tending to increase this activity have to consider the specific cases. A detailed general survey has to be done to appraise the present research objectives of the different groups and the main difficulties they experience to attain them.

The global situation allows, however, proposal of some general cooperation schemes which will depend on the specific cases being considered.

A. Human Ressources

The lack of PV specialists is one of the major deficiencies of the Region, preventing the establishment of solid research groups that might be the origin or support for local industries. Special programmes should be organized with external cooperation to palliate this deficiency.

1. Scholarships for Latin American researchers allowing their training in PV advanced technologies. These scholarships should be granted however on the basis of well defined PV programmes in local laboratories, i.e. they should be part of a broader effort to develop PV activities.
2. Visits of well known PV specialists to different Latin American laboratories for periods ranging from one to several months. These scientists should help in the definition of sound research objectives and/or cooperate in the research programmes. The same philosophy should be applied to promote the organization of regional PV meetings where specific difficulties of PV research could be discussed. These meetings should combine two types of activities: the exchange of views and news within the Region and the organization of short courses on the theoretical and experimental aspects of PV materials and devices.

3. The possibility of establishing a regional "centre of excellence" with research and teaching activities in photovoltaics should be seriously considered and encouraged. This centre should be the place where researchers and students of the Latin American region could come to perform advanced research, to work on specific PV technologies or to obtain higher degrees. The analysis of the present photovoltaic R&D and industrial activities in Latin America indicates that Brazil is the best candidate to host such a centre. The Laboratory of Photovoltaic Conversion at Unicamp could be a good choice for advanced photovoltaic research and development. The reasons governing this choice are the following: i) it is the most experienced group of the Region; ii) the Laboratory is already acting as a kind of centre of excellence through its cooperative programmes with other Brazilian research groups and with laboratories of Argentina and Colombia, and iii) Campinas is the region where the Brazilian microelectronics industry is established, i.e. this gives an extra opportunity for visitors to know about industrial aspects of the parent industry.
4. United Nations agencies (mainly UNESCO and UNIDO) should establish special programmes for allocating funds: 1) to help active researchers in the field to participate in international PV conferences and 2) for the purchase of books, journals, conference proceedings and technical reports.

B. Cooperation Programmes.

1. UNIDO should study the possibility of establishing programmes to help selected research laboratories that have difficulties with equipment maintenance and with the purchase of : inexpensive items like electronic components, special gases, quartz, chemical reagents, etc. The local unavailability of these goods often provokes the complete stop of the research activity for long periods of time. The amounts needed vary from laboratory to laboratory but they do not exceed 10,000 to 20,000 US dollars/year.
2. The United Nations system should study the possibility of promoting "research joint ventures" between laboratories in the Third World and advanced laboratories in the industrialized countries. As an example we can imagine a research laboratory in Latin America collaborating with two or three European groups in a specific PV research programme being sponsored by the European Communities.



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Consultative Group on Solar Energy
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REPORT*

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I. Introduction

1. The Workshop on the Establishment of a Consultative Group on Solar Energy Research and Applications (COSERA) was held on 8-10 December 1986 at UNIDO headquarters in Vienna, Austria.

2. The Workshop was attended by 11 experts on solar energy from developed and developing countries, and UNIDO Secretariat staff. The list of participants is attached as Annex I.

3. The Workshop's objective was to consider and present recommendations on the possible establishment of a Consultative Group on Solar Energy Research and Application. The COSERA would be a mechanism for mobilizing international co-operation directed towards enhancing the effectiveness of solar energy research in developing countries and the transfer of results into industrial production, commercialization and widespread use. The COSERA would draw upon the model of the Consultative Group on International Agricultural Research (CGIAR), particularly in relation to the mobilization of donor interest and support. The Workshop was intended to be a preliminary activity leading to wider consultations with donor agencies and developing country institutions.

II. Opening of the Workshop

4. The Deputy Director-General of UNIDO's Department for Industrial Promotion, Consultations and Technology, who opened the Workshop, stated that the inception of a solar energy industry in many developing countries had to be nurtured along with the strengthening of the countries' appropriate scientific and technological capabilities. This approach was also derived from UNIDO's watchwords since the late 1970s: "Industry for Energy and Energy for Industry".

5. He recalled the series of international conferences urging the establishment of a co-operative mechanism on solar energy and drew attention to the promotional and information activities UNIDO had been pursuing towards this end. Next to agriculture, UNIDO considered solar energy as the sector most deserving of promotion of international

co-operation in research. It is infinitely renewable, abundant, and widely available in both developed and developing countries. He outlined some of the circumstances making it opportune for the Consultative Group to be set up, citing the example of the success of CGIAR and noting that several potential donors have already indicated their interest in such a group for solar energy. He emphasized the crucial role the experts would have to play in the establishment and operation of the Group.

III. Election of Officers

6. The Workshop unanimously elected Mr. O.A. El-Kholy, Kuwait, as Chairman and Mr. I. Chambouleyron, Brazil, as Rapporteur.

IV. Background

7. Welcoming the initiative of the UNIDO Secretariat and the timeliness of its proposal, the Workshop noted that the establishment of the Consultative Group had to be considered from the broader perspective of the international economy, and from the perspective of the status of co-operation in the solar energy field itself. The participants commended the Secretariat for providing the basic background paper which provided an excellent starting point for the discussions of the Workshop (see list of UNIDO documents in Annex II) and supplemented the information given in the background paper with the latest developments in their specialities and in activities worldwide.

8. The Workshop noted that in April 1983, experts meeting at the International Forum on Technological Advances and Development in Tbilisi, USSR, preparatory to UNIDO's Fourth General Conference, had recommended the establishment of a Consultative Group for Solar Energy Research and Application. Solar energy had also received attention at the High-Level Expert Group Meeting in Oslo, Norway, on Energy and Industrialization. At this meeting proposals made on specific activities in solar energy that could be undertaken by UNIDO, included the evaluation of the potential for solar industrial processing heat in the developing countries, possibly leading to local manufacture and assembly

operations. It had also been proposed that UNIDO should promote research leading to the manufacture of solar photovoltaics.

9. Finally, at UNIDO's Fourth General Conference in August 1984, political impetus was given to the earlier recommendations by the adoption of a resolution calling on UNIDO to "promote co-operation between institutions engaged in research and development on new and renewable sources of energy". This recommendation followed the same spirit as that of the Nairobi Plan of Action adopted by the United Nations Conference on New and Renewable Sources of Energy in 1981.

10. A review of selected research institutes in developing countries carried out by UNIDO in 1982, and updated in 1985/1986, showed that out of a 115 institutes included in the review, 43 were involved in research on photovoltaics (solar cell and systems), 25 with solar thermal collectors, 15 with solar thermal systems, and 6 with selective coatings, 10 were doing research on materials, and the rest on photo-electrochemical conversion. 22 institutes indicated that they were also taking solar radiation measurements. Main application areas were solar drying (47), water heating (33), water treatment (26), cooling and refrigeration (24), solar cooking (16), and water pumping (13); 6 institutes were engaged in research on industrial process heating and 4 on solar energy for greenhouses. The research and development budgets ranged from US\$10,000 to several millions. The great majority had budgets of US\$100,000 to 200,000, with an average professional staff of 5. However, it is not at all evident that activities are being harmonized in such a way as to achieve maximum impact in the energy sector globally, particularly in developing countries.

11. The Workshop was of the opinion that several factors thus indicate that the stage has now been reached where a more decisive thrust towards co-operation is needed. Among the factors are the relatively stagnant trends in solar energy equipment production and shipments; the somewhat conflicting trends in regard to the quantum of research funds being channelled into the field of solar energy; the availability of a certain amount of experience in the utilization of solar energy equipment by the developing countries; the existence of a large number of institutions in developing countries carrying out research in the field of solar energy;

and not least, the widely expressed desire for international co-operation. This, together with the ongoing though limited, co-operation at the regional level calls for the establishment of a Consultative Group on Solar Energy Research and Application (COSERA) at the international level, with the aim of promoting a critical mass of international effort related to solar energy research and application, in particular for the benefit of the developing countries.

V. Issues identified in the discussions

12. In presenting their papers and discussing the various aspects of solar energy and the concept of a consultative group, the participants highlighted the following main issues:

- (a) A recognition that solar energy is an important tool for development. Solar energy is already competitive for remote area applications, but the target must be to widen its market in the developing countries. With appropriate research and development, cost could be substantially reduced, thus opening up new opportunities in developing countries for its application. In addition, through the application of advanced technologies, solar energy devices could be made more efficient, reliable and simple to operate.
- (b) Solar energy should not be viewed in isolation from other sources of energy. It has to be an integral part of the country's overall energy plans and development objectives. Consequently, its role in overall development planning has to be clearly defined. These two requirements make it necessary that solar energy for developing countries be programme-oriented rather than a collection of isolated projects. Such a programme would have to cover all aspects of activities in the field of solar energy, from research and the development of technology to socio-economic aspects, production, commercialization etc. To enable solar energy to be included in overall development planning, up-to-date and appropriate data would have to be made available. This would require both

monitoring and the establishment of information systems. It was also stressed that solar energy activities needed a national focal point or government agency responsible for its promotion and development.

- (c) Solar energy in general, and especially in the developing countries, faces a number of major constraints. These constraints can be categorized as economic, technical, institutional and social.

Solar energy devices tend to have a high initial investment cost together with a small market in the developing countries. This is a vicious circle which must be broken to expand markets and reduce costs. Furthermore, with the current low oil prices at the present time, compared with a few years ago, this has a dampening effect on solar energy development. However, this situation which is dependent on political as well as economic factors may not be an appropriate signal for efforts in the developing countries on solar energy. Finally, the energy markets in developing countries in which solar is competing, tend to be regulated by governments, i.e. heavily subsidized. This makes it very difficult for a new source of energy to break into these markets without equal economic support.

Many solar energy devices on the market in some developing countries are poorly made and, therefore, have low levels of reliability. Should this pattern continue, solar energy will acquire a bad reputation among consumers that will be hard to change. In developing countries there sometimes is a lack of scientific leadership in solar energy research. Thus research and development in the field lacks clearly-defined and relevant priorities. There is also a marked shortage in many cases of trained specialists and technicians in the field of solar energy. These have a negative impact on research, demonstration and commercialization.

The development and application of new technologies, such as solar, is often handicapped in developing countries by the poor linkages among the different sectors of the economy and the government departments involved. Different public institutions often operate with little or no regard for the effect of their actions on other sectors of the economy. The introduction and development of solar energy technology will require institutional co-ordination among the many government departments concerned. These institutional constraints will have to be overcome, otherwise even when low cost, efficient and reliable solar energy systems are developed, their dissemination will be severely hindered in the developing countries.

Any new technology which has to be absorbed by the commercial and household sectors requires a widespread and extensive public education and promotion programme. A technology such as solar energy is too often seen as a black box and is not also related to the social conditions of the country. For solar energy to make a breakthrough it is essential that a public awareness programme be developed and implemented. This should be aimed at all levels of society from school children to policy makers.

- (d) Considerable research and application on solar energy has been going on in both developed and developing countries. A certain amount of co-operation has been undertaken between developed and developing countries, but very little as yet between the developing countries themselves. There is still plenty of room for research, demonstration and commercialization, especially reflecting local conditions, priorities and capabilities in the developing countries. This research and development work must have as its basic goals cost reduction, reliability and simplicity of operation.
- (e) An area where developing countries appear to lack adequate effort can be classified as research-related activities for solar energy, particularly techno-economic studies. These

research programmes have to be undertaken as important adjuncts to the technical research and development work on solar energy. From experience in other energy areas, multidisciplinary research groups comprising scientists, engineers, economists and sociologists may be the most appropriate for this solar energy research-related activity.

- (f) The Group endorsed the proposal of UNIDO for the establishment of a Consultative Group on Solar Energy Research and Application. It noted that the concept of a consultative group on solar energy with programme-oriented proposals has also been welcomed by a number of donor countries and agencies and that UNIDO had received expressions of interest, both written and oral, from several donors. It was also felt that the CGIAR could serve as a model and its experience be a useful example for the operation of the COSERA.

13. The Workshop divided into two working groups to examine (a) the policy aspects of the Consultative Group, and (b) technical considerations, respectively.

VI. Conclusions and Recommendations

(a) Policy aspects

14. The Workshop envisages the Consultative Group on Solar Energy Research and Applications (COSERA) as an institutional group of scientific establishments, donor organizations and financing agencies. the institutions will be ones of recognized achievement with a standard of excellence in research and applications of solar energy, or interest in the promotion of the harnessing of solar energy to development needs in various parts of the world. The members representing these institutions will be distinguished personalities of recognized standing in the field. The COSERA, if it is to achieve the objectives envisaged by the Workshop and detailed hereunder, needs to have the prestige and credibility essential for playing this role.

15. The COSERA is thus seen as a high-level forum for identifying, through collective interaction of its members: (a) the priority needs in research and applications that would promote the widespread use of solar energy in the overall development effort in the variety of situations in different parts of the world[as well as (b) the donor sources for financing activities to meet such needs. It would thus act as a catalyst that would achieve optimum results from the multitude of efforts in many organizations and in different countries. In its first phase of operation, COSERA will achieve such results through:

- assisting in establishing and/or strengthening links and synergy between the various actors in the field (donor agencies, governments, industry, scientists, citizen groups etc.);
- contributing to the achievement of maximum effectiveness in the flow of funds to research establishments, whether governmental or in industry, and mobilizing more funds for the high priority and most promising activities in the field, as identified through its deliberations;
- promoting closer integration of the results of solar energy research, development and applications, in the overall energy plans of countries or regions and within the framework of their development planning for a better life; and
- strengthening national capabilities at all levels (decision makers, planners, scientists, technicians, industrialists, bankers, promoters, and the public) in harnessing solar energy effectively to specific national needs.

16. It is of particular importance at this stage that the COSERA be project-oriented, rather than restricted to conceptual formulations. It would thus consider proposals for research, development and applications for recommendation to funding agencies, as well as propose to interested parties projects it considers of high priority, and indicate its willingness to help them, as they wish, in fulfilling their specific

tasks in promoting what it considers as the most appropriate venues for harnessing solar energy to their specific needs and local conditions. This covers the whole range of activities from basic research to applied research, development work, engineering, production, active promotion and widespread utilization, as well as monitoring and evaluating progress in these activities.

18. As the COSERA establishes its standing and prestige with the various types of organizations, national, regional and international, through its operations along the advisory and support roles outlined above, it could move into other phases in which it could embark on other activities and operations, as deemed appropriate at the time. These could include:

- supporting training and manpower development in the field of solar energy research and applications at all levels;
- establishing and/or strengthening mechanisms for the exchange of experiences and information;
- supporting the authoring and publication of directories, guidebooks, and other publications providing information on commercially exploitable technology, criteria and parameters in satisfying national needs, effective promotion and marketing of solar energy applications; and
- setting up and/or strengthening existing centres of excellence, at regional and international levels, as deemed necessary and useful.

18. The COSERA is not an intergovernmental body, nor will it "dictate" what needs to be done. It should endeavour to harmonize to the extent possible the variety of ongoing efforts and support new worthwhile ones. It will have to function with a minimum of legal or bureaucratic constraints, relying mainly on its prestige and credibility in achieving its objectives, and in securing a minimum level of obligation on the part of participating organizations, particularly donor agencies, in the

provision of information and willingness to discuss the results of their various efforts and experiences. The COSERA will not preclude any bilateral co-operation, now or in the future, nor will it substitute efforts in countries or interfere with existing commercial flows. It could, on the other hand, contribute to the establishment of viable solar energy industries in developing countries, and open up potential markets to international trades as well as promote sharply-focussed research linked to industrial application and widespread appropriate applications.

19. In order that the concept of COSERA outlined above be operationalized, the Workshop recommends that the UNIDO Secretariat set up a task force to elaborate these general indicative guidelines, and explore in more depth the level of interest, the modes of co-operation and involvement of those bodies, within and without the UN system, identified as desirable and interested participants in the establishment of the COSERA. The Workshop further recommends that on the basis of the findings of the task force, UNIDO organize a meeting in which COSERA will be established. It is hoped that such a meeting be organized by UNIDO before the end of next year. In the meantime, UNIDO is urged to continue its activities in providing technical assistance and information, publishing directories and other activities in the field of solar energy development and application.

(b) Technical considerations

20. For the formation of any group such as COSERA, it is important at an early stage to identify clearly subject areas of R&D and suitable applications where effective international co-operation may be primarily utilized. Specific areas in this context would be considered under two broad headings, these being solar photovoltaic and solar thermal. Many of the aspects considered under testing, reliability and materials research are common to both technologies.

Areas of R&D

- Reliability should be established for systems and components under a wide range of climatic conditions. Use could be made initially of existing testing facilities in such countries as

the USA, Australia and those in the European Economic Community. These tests should address important issues such as module encapsulation, durability of interconnections, and materials degradation.

- Efficiency testing. This is seen as a vital area relevant to the reduction of total system cost. There is a requirement for testing under well-defined simulated radiation conditions, and for practical outdoor testing. It is anticipated, initially, that such tests could be arranged on a co-operative basis with well established laboratories in developed countries.
- Systems research. In an attempt to develop optimized systems, it is recommended that attention be focussed on both high efficiency - high cost systems, and on lower efficiency - low cost systems. Sufficient emphasis should be given to balance of system component design to ensure good matching.
- Although many programmes of research into materials and devices are being carried out by developed countries, the Workshop recommends that these should also be performed in the developing countries. The existence of such research groups could ultimately become the origin of or support for local industry.

Indicative Applications

(i) Photovoltaic systems. These should include the following:

- water pumping and treatment
- communications
- medical refrigeration
- village lighting
- rural educational radio and T.V.
- small-scale power for rural industries

21. These should all be examined with a view to gaining hands-on experience and aiding in the training of locally based technicians. It should be realized that in many remote regions such systems are already cost-effective and are sometimes the only logical solution to the provision of off-grid power. Even though the impact on overall energy economies may be small, such systems could substantially enhance the quality of life in rural communities.

(ii) Solar thermal. These should include the following:

- water systems, including desalination and treatment
- drying systems to reduce post-harvest losses
- cooking and food processing
- cooling and refrigeration
- solar water heating (for hospitals, medical applications, tourist hotels, laundries, and food processing plants)
- passive solar energy applications in housing

22. The Workshop emphasized that the widespread use of solar thermal technologies will enable developing countries to lessen their dependence on imported fossil fuels, improve their balance of trade situation substantially, as well as maintain the health of their environment.

23. One of the primary duties of the task force to be set up to consider the establishment of the COSERA would be to build up a tentative portfolio of R&D and application projects in developing countries suitable for promotion at the international and regional level. In this task it would be important to examine existing projects in various regions which may be appropriate for funding, and to evaluate the potential for projects in other regions where none are currently in existence.

24. Such a portfolio of R&D and application projects necessitates that, as mentioned in the Recommendations on Policy Aspects (p.9, para. 18), consideration be given in due course to the establishment or strengthening of existing centres of excellence in developing countries, suitably located to serve as specialized centres of international scope for research, development and formal training of professional and technical staff. It may be advantageous to invite specialists from developed countries to advise in the establishment and direction of new programmes. However, every effort should be made to utilize local or regional experts in this capacity wherever possible.

ANNEX I

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ANNEX II

LIST OF DOCUMENTS

Aide Mémoire

Issue Paper Establishment of COSERA: Issue Paper
prepared by the UNIDO Secretariat

Conference Room Papers:

- | | |
|---------|---|
| CRP. 1 | Provisional Agenda |
| CRP. 2 | Provisional Programme of Work |
| CRP. 3 | Provisional List of Participants |
| CRP. 4 | Provisional List of Documents |
| CRP. 5 | Directory of Solar Research Institutes
in Developing Countries (Addendum 1986) |
| CRP. 6 | Consultative Group on International Agricultural
Research (CGIAR) - a brief review |
| CRP. 7 | A review of economic and technological requirements
of solar cells: status and research directions of
polycrystalline thin film devices, by T.J. Coutts |
| CRP. 8 | New concepts in the field of thermal conversion of
solar energy, by V. Wittwer |
| CRP. 9 | Solar Thermal Technologies, trends in research,
development and commercialization, by Prof. W.S.
Chambouleyron |
| CRP. 10 | Research and Development of Solar Energy Technology
in India, by Prof. T.K. Moulik |
| CRP. 11 | Solar Energy in Latin America, by Prof. I.
Chambouleyron |
| CRP. 12 | Solar and renewable energy in Zimbabwe and SADCC,
utilization and future development, by J.E. Stevens |
| CRP. 13 | Working paper for the preparation of a
Prefeasibility Study for an Islamic Programme |
| CRP. 14 | Prefeasibility Study, Islamic Network on Renewable
Energy Sources |

Background documents

Solar cell materials and fabrication technologies,
by K.W. Boer

Study on amorphous silicon solar cells, by A. Madan

Global trends in technology, policy and firm
strategy in photovoltaics, by K. Hoffman

Solar powered Stirling engines and their potential
uses in developing countries, by W.T. Beale

Directory of Solar Research Institutes in Developing
Countries, prepared by the UNIDO Secretariat
(UNIDO/IS.341/Rev.2)